U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-253 994

WATER QUALITY DATA DURING SEPTEMBER 10-13, 1974 AT WARD COVE AND TONGASS NARROWS, ALASKA

ENVIRONMENTAL PROTECTION AGENCY

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

APRIL 1975

176040

WORKING PAPER NO.
E.P.A./910-8-76/097

PB 253 994

WATER QUALITY DATA DURING SEPTEMBER 10-13, 1974 AT WARD COVE AND TONGASS NARROWS, ALASKA

U.S. ENVIRONMENTAL
PROTECTION
AGENCY
ALASKA
OPERATIONS OFFICE
AND REGION X
SURVEILLANCE AND
ANALYSIS DIVISION
SEATTLE, WASHINGTON

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA-910/8-76-097	2.	3. Recipient's Accession No.

4. Title and Subtitle
Water Quality Data During September 10-13, 1974 at Ward Cove and Tongass Narrows, Alaska.

5. Report Date
April, 1975

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Alaska Operations Office
U.S. Environmental Protection Agency
Anchorage, Alaska 99501

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Surveillance and Analysis Division
U.S. Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101

13. Type of Report & Period Covered
Final Report

14.

15. Supplementary Notes

16. Abstracts A study was made in September, 1974, of the estuarine waters of Ward Cove and the adjacent marine waters of Tongass Narrows which are influenced by the wastewater discharges from the Ketchikan Pulp Mill Company, located a few miles north of Ketchikan, Alaska. The Ketchikan Pulp Company operates a magnesium base bisulfate process pulp mill at this cove. Production over the past few years has varied from 580-615 tons of dried dissolving grade pulp per day. The brief study reported here was undertaken to determine the present quality of the waste-receiving waters and to determine the improvements, if any, that have occurred in water quality as a result of the installation of a primary treatment system at the mill for removal of settleable solids. No attempt was made to assay the effect of installation and operation of the mill's secondary sewage treatment facility on water quality.

17. Key Words and Document Analysis. 17a. Descriptors

Water quality
Water analysis
Sampling
Industrial wastes
Pulp mills
Waste water

17b. Identifiers/Open-Ended Terms
Ward Cove, Alaska
Tongass Narrows, Alaska

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Distribution unlimited.	UNCLASSIFIED	61
	20. Security Class (This Page) UNCLASSIFIED	22. Price $ - 2.25

WATER QUALITY DATA DURING

SEPTEMBER 10-13, 1974

AT

WARD COVE AND TONGASS NARROWS, ALASKA

U.S. ENVIRONMENTAL PROTECTION AGENCY
ALASKA OPERATIONS OFFICE
ANCHORAGE, ALASKA
AND
REGION X, SURVEILLANCE AND ANALYSIS DIVISION
SEATTLE, WASHINGTON
APRIL 1975

This report has been reviewed by EPA Region X and is approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

A working paper presents results of investigation which are, to some extent, limited or incomplete. Therefore, conclusions -- expressed or implied -- may be tentative.

CONTENTS

	Page
INTRODUCTION	1
Problem	1
Purpose	2
Scope of Study	4
Authority	4
SUMMARY AND CONCLUSIONS	5
STUDY AREA	9
General Description	9
Climatic Conditions	10
Oceanography	11
Water Uses	12
Previous Studies	12
WATER QUALITY STANDARDS	16
SAMPLING PROGRAM	18
Sampling Stations	19
Sampling Periods	19
Methods	21
RESULTS AND DISCUSSION	23
Temperature and Salinity	23
Sulfite Waste Liquor	25
Dissolved Oxygen	32
pH	36
Color	36
Chemical Aspects of Bottom Deposits	37
Visual and Biological Aspects of Bottom Deposits	40
REFERENCES CITED	43
APPENDIX TABLES	44

LIST OF FIGURES

Figure	Description	Page
1	Tongass Narrows and Ward Cove	9
2	The Ward Cove - Tongass Narrows Study Area and location of Sampling Stations (the area to the right of the dotted line depicts distribution of Sulfite Waste Liquor).	20

LIST OF FIGURES

Figure	Description	Page
1	Tongass Narrows and Ward Cove	9
2	The Ward Cove - Tongass Narrows Study Area and location of Sampling Stations (the area to the right of the dotted line depicts distribution of Sulfite Waste Liquor).	20

LIST OF TABLES

Table	Description	Page
1	Temperature, salinity, and density with depth in meters at Stations 8 and 11	24
2	Sulfite Waste Liquor concentrations (mg/l) with depth in meters in Ward Cove & Tongass Narrows Sept 10, 1974 0930 - 1300 Hrs.	26
	1500 - 1900 Hrs.	27
	Sept 11, 1974 1600 - 1900 Hrs.	28
	Sept 12, 1974 1200 - 1600	29
3	Dissolved Oxygen concentrations (mg/l) at 1 meter in Ward Cove and Tongass Narrows 9/74	33
4	Ward Cove Sediment Analysis 9/13/74	38

APPENDIX TABLES

1A	Salinity with depth (meters) in Ward Cove and Tongass Narrows 9/10/74 0930 - 1300 Hrs.	45
1B	Temperature " "	46
2A	Sulfite Waste Liquor concentrations (mg/l) with depth (meters) in Ward Cove and Tongass Narrows, 1968 - 1969	47
3A	Dissolved Oxygen concentrations (mg/l) with depth (meters) in Ward Cove and Tongass Narrows 9/10/74 0930 - 1250 Hrs.	49
	1555 - 1830 Hrs.	50
	9/11/74 1600 - 1900 Hrs.	51
4A	Dissolved Oxygen concentrations (mg/l) at selected depths (meters) in Ward Cove and Tongass Narrows 1968 - 1969	52
5A	Secchi disk (20CM) measurements in meters for Ward Cove and Tongass Narrows 9/10/74 0900-1300	54

INTRODUCTION

Problem

A study was made in September 1974 of the estuarine waters of Ward Cove and the adjacent marine waters of Tongass Narrows which are influenced by the wastewater discharges from the Ketchikan Pulp Mill Company, located a few miles north of the community of Ketchikan, Alaska. The Ketchikan Pulp Company operates a magnesium base bisulfate process pulp mill at this cove. Production over the past few years has varied from 580 - 615 tons of dried dissolving grade pulp per day.

Prior to 1971, some strong waste liquors were periodically discharged without treatment as a routine practice, one not uncommon in the pulping industry at this time. Since then, the mill has installed storage facilities to retain all strong liquors for subsequent re-use. Current wastewater processing consists of primary treatment, screening then burning of woodroom waste solids, and chemical recovery units that collect, concentrate, and burn strong pulping liquors. In the latter process most (90+%) magnesium oxide and sulfur dioxide are recovered for re-use. About 42 million gallons per day (mgd) of pulp processing wastewater are discharged to Ward Cove. Approximately 15 mgd are provided primary treatment for solids removal prior to discharge. Sewage wastes are given secondary treatment, then discharged to Ward Cove subsequent to chlorination. The pulping wastewaters contain significant quantities of sulfite waste liquors and have a high biochemical oxygen demand (BOD), even though the BOD is reduced

as a consequence of removal of much settleable solids in the primary wastewater treatment process.

The effects of the Ketchikan Pulp Company's discharges on water quality in Ward Cove and Tongass Narrows were investigated in 1968 and 1969 by the Federal Water Quality Administration in cooperation with the U.S. Fish and Wildlife Service. Interpretation of data from this investigation and from earlier studies by the State of Alaska and the Federal Water Quality Administration established the significance of degradation of water quality in Ward Cove and the adjacent waters of Tongass Narrows that had been caused by long term discharge of inadequately treated pulp mill wastes (1).

A primary treatment plant for removal of solids from pulp processing wastewaters was installed and began operation in early 1973, and a secondary treatment facility for treatment of sewage wastewaters was constructed and put into operation in mid 1973.

Additionally, a log-bundle transfer facility, which lifts bundled logs from the water to a "dry" deck for subsequent processing, was installed and began operation in 1973. This facility has reduced the amount of bark solids previously deposited in the northeast corner of Ward Cove.

Purpose

The waters of Ward Cove and the contiguous reaches of Tongass Narrows had not been sampled by a water quality regulatory agency since the installation of present wastewater treatment systems at

the pulp mill. The brief study reported herein was undertaken to determine the present quality of the waste receiving waters and to determine the improvements, if any, that have occurred in water quality as a result of the installation of a primary treatment system for the removal of settleable solids from the pulp processing wastewaters at the mill. No attempt was made to assay the effect of installation and operation of the mill's secondary sewage treatment facility on water quality.

It should be pointed out that a seafood processing plant (cannery), the Ward Cove Packing Company, also discharges wastewater to Ward Cove, and that no attempt was made to evaluate the effect of its present discharges, which are only seasonal, on water quality. This facility is located near the mouth of Ward Cove, on the side opposite the pulp mill. The following questions were answered in whole or in part as a result of this study:

1. What is the present water quality in Ward Cove and Tongass Narrows compared to previous studies, and to the Alaska Water Quality Standards criteria for dissolved oxygen, pH, residues, sludge deposits, and toxic substances?
2. What improvements in water quality, if any, have occurred since installation and operation of a primary treatment system by the Ketchikan Pulp Mill Company for the removal of settleable solids from its pulp processing wastewaters?
3. What is the magnitude of the area of Ward Cove and Tongass Narrows that is affected by sulfite waste liquors discharged from the pulp mill?

Scope of Study

Chemical, physical, and very limited biological data were collected from Ward Cove and Tongass Narrows concurrently while a routine in-plant monitoring survey was made of the Ketchikan Pulp Company mill. No attempt is made herein to relate the findings of the in-plant study with those of the receiving water surveys. Both were accomplished during the week of September 9-12, 1974. In the receiving waters, primary efforts were made to collect temperature, salinity, dissolved oxygen, conductivity, pH, and sulfite waste liquor data.

Bottom samples in the study area were collected to determine visual presence of settleable solids in the form of pulp fibers as recently formed sludge mats, if any; for chemical composition to assay stage of decomposition of sludge formations known to be present during previous studies; and for general biological information pertaining to macroscopic (readily visible) plants or animals that might inhabit the bottom deposits. No samples were obtained to evaluate floating or suspended microscopic plant or animal populations.

Authority

Section 104 of the Federal Water Pollution Control Act Amendments of 1972 authorize the Administrator of the U.S. Environmental Protection Agency to conduct studies relating to the causes, control, and prevention of water pollution.

SUMMARY AND CONCLUSIONS

A brief water quality survey was conducted in the estuarine waters of Ward Cove and the adjacent marine waters of Tongass Narrows near Ketchikan, Alaska, during the week of September 9, 1974 to determine the present influences of waste discharges from the Ketchikan Pulp Mill Company following the installation and operation of its primary treatment system for pulping wastewaters, and to assay any improvements in these receiving waters as a consequence of equipping the mill with this treatment facility. Data obtained from 9 stations in Ward Cove and 9 stations in Tongass Narrows consisted primarily of measurements for sulfite waste liquor, dissolved oxygen, temperature, pH, conductivity, and salinity at depths of 1, 7, 10, and 12 meters, and chemical, visual, and biological examination of bottom deposits. Additionally, Secchi disc measurements were made at each of the 18 stations in the survey area.

The Alaska Water Quality Standards criterion for dissolved oxygen in marine waters is 6.0 mg/l. Data from the September 1974 water quality survey reveal that:

1. about 24% (63) of all samples (266) had less than 6.0 mg/l of dissolved oxygen (D.O.);

2. 69% of all surface samples (1 meter) had D.O. values that did not exceed 6.0 mg/l;

3. within Ward Cove the D.O. was less than 6.0 mg/l 85% of the time in the top 1-meter layer;

4. about 37% of all samples (surface and at depth) in Ward Cove had less than 6.0 mg/l, with D.O. below 6.0 mg/l in 75% of the samples at Station 1 where the D.O. was observed to be 1.0 mg/l on one occasion;

5. no perceptible major improvements in the dissolved oxygen concentrations of Ward Cove and the adjacent waters of Tongass Narrows since the 1968-1969 study based on comparisons of the average dissolved oxygen values found in Ward Cove and Tongass Narrows surface samples (1-meter) and on comparisons of the average dissolved oxygen for these waters at all depths through 12 meters.

The same standards criterion for toxic substances in marine waters is that their concentrations shall be less than those levels which cause tainting of fish, less than acute or chronic problem levels as revealed by bioassay or other appropriate methods, and below concentrations affecting the ecological balance. Sulfite waste liquors at concentrations of 50 mg/l are toxic to phytoplankton and fishfood organisms; at concentrations of 10 mg/l, they are damaging to some immature forms of shellfish.* Data from the survey reveal that:

1. sulfite waste liquor (SWL) concentrations of 50 mg/l occurred in 21% (54) of all samples (257) taken at the 1, 7, 10, and 12 meter depths and 32% of all samples had SWL concentrations of 10 or more mg/l;

2. 82% of all surface samples had more than 50 mg/l of SWL, and 92% had more than 10 mg/l;

3. 100% of the near-surface stations in the 2.0 square mile study area had concentrations of 50 or more mg/l of SWL at one time or another during the survey period, and 10 mg/l concentrations of SWL were observed throughout the 1-meter depth during the September survey period or 97% of the time, except in only two instances, once each at Stations 2 and 15 which are subjected to strong flushing action and/or extensive dilution;

4. the average concentration of SWL in the surface waters of Ward Cove (242 mg/l) was significantly higher than in those of Tongass Narrows (109 mg/l);

*Forty-eight hour bioassays of effects of magnesium oxide base sulfite waste liquor show a 20% mean response at a concentration of 40 mg/l, but concentrations as low as 10 mg/l have produced toxic responses in as much as 5% of some populations sampled.

5. no perceptible major improvements in the magnitude of concentrations of sulfite waste liquor concentrations in Ward Cove and the adjacent waters of Tongass Narrows since the 1968-1969 study, as based on the general similarities in SWL concentrations during the two surveys;

6. red (strong) waste liquors were periodically discharged as a routine practice, one not uncommon in the pulping industry during the 1968-1969 study period. This practice had been discontinued by the time of the September 1974 survey; the absence of such discharges therefore may account for the occasionally very high sulfite waste liquor concentrations (more than 1000 mg/l) found during the 1968-1969 study compared to those measured in September 1974 (less than 1000 mg/l). Thus the lower sulfite waste liquor concentrations found during the 1974 sampling period, that is, always less than 1000 mg/l, probably reflects a minor improvement in the cove as far as sulfite waste liquor is concerned.

The quality of waters in the survey area in relation to the standards criteria for pH was not determined because of malfunctions in the sampling equipment soon after the beginning of the survey. The five measurements made for pH in the upper reaches of Ward Cove, however, were within the standards criteria of 7.5 - 8.5.

Previous studies of these waters showed that the bottom deposits in much of the study area, particularly Ward Cove, consisted of sludge, but chemical analysis to characterize these deposits were not made. Such analysis for the 1974 survey showed very high concentrations of organic nitrogen (3.6 to 7.5 g/kg) and total sulfides (1.5 to 4.3 g/kg). The chemical oxygen demand ranged from 147 to 655 g/kg, and the volatile solids ranged from 11.1 to 46.9% at the 8 bottom stations that were chemically analyzed. Sludge was found at all other stations in Ward Cove and at Stations 10, 11, and 12 in Tongass Narrows, as visually determined.

Visual and biological observations of the bottom deposits and surface waters showed no hydrogen sulfide bubbles in the Ward Cove area; these undoubtedly were present during the 1968-1969 study but not reported. Small mats of sludge and pulp fibers observed in surface reaches of Ward Cove near mill outfalls were not observed during the 1974 survey. Polychaete worms, not of frequent occurrence in the samples from the 1968-1969 study, were noted at all but two stations, 1 and 6, in Ward Cove during the 1974 survey. Thus, it was apparent that some improvement had occurred in the bottom deposits, even though there were no major improvements elsewhere in the study area.

STUDY AREA

General Description

Ward Cove is an estuary located about 5 miles northwest of Ketchikan (Figure 1), connecting with Tongass Narrows. The cove is about 0.5 of a mile at its widest point and 1 mile long; it is 0.3 of a mile wide at its mouth where the water is about 55 meters deep, becoming relatively shallow at the head of the cove with a general depth of 5 to 10 meters. The cove has an area of about 0.46 square miles. Ward Cove enters at the head of the cove and is the principal source of fresh water.

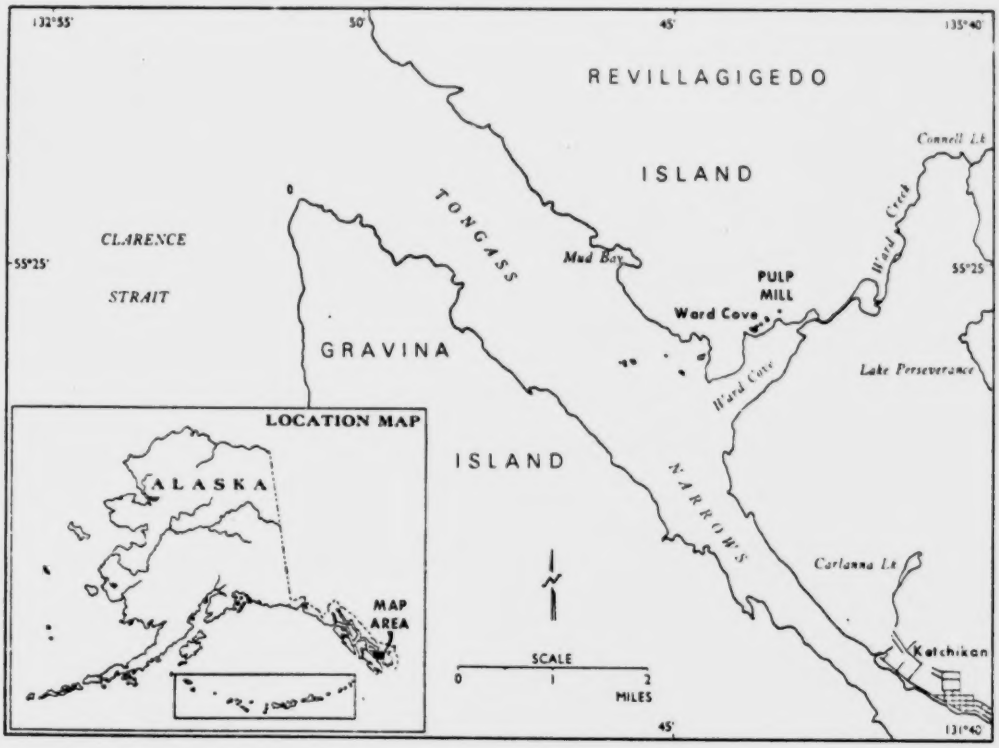

Figure 1 Tongass Narrows and Ward Cove

Much smaller streams enter the cove along the south shore. Ward Creek is regulated by a dam, and the associated reservoir, Lake Connell, is a water supply for the mill.

Development around Ward Cove, other than the Ketchikan Pulp Company and the Ward Cove Packing Company, consists of an abandoned fish reduction plant and a few homes located near the head of the cove and along its south shore.

Climatic Conditions

The Ketchikan-Ward Cove area is in the cold maritime belt of Southeastern Alaska. Average rainfall is 150 inches annually, and annual snowfall is less than 50 inches. Prevailing winds blow from the southeast and occasionally from the northwest. The mean low temperature for January is 28°F, and the mean high is 38°F. Ice rarely forms on the marine waters of Ward Cove and Tongass Narrows.

The input of non-brackish water to the cove comes mainly from the mill outfalls and Ward Creek. The flow of wastewater from the pulp mill is about 42 million gallons per day (mgd), or 57 cubic feet per second (cfs). Ward Creek in 1957 had a yearly mean discharge of 46 cfs, with a maximum flow of 1200 cfs and a minimum of 0.8 cfs. The discharge of water from Ward Creek is partially dependent on pulp mill water use since the reservoir near the head of the stream serves as the pulp mill water source. The daily water input to Ward Cove fluctuates between 1296 and 69.8 cfs with an average daily input of 115 cfs from both mill and natural sources. Watershed flow retention

is moderate because of great amounts of precipitation and steep gradient of the watershed.

Oceanography

In marine waters of northern latitudes, annual variations in temperature and salinity cause seasonally characteristic density profiles throughout the water column. Typically, during fall and early winter, the surface waters cool, become more dense than subsurface waters, and sink, causing complete vertical mixing. In winter, intense storms increase horizontal mixing. Tidal ranges at Ketchikan vary from a maximum high tide of 18.8 feet to a minimum low tide of minus 4.1 feet. A non-tidal current flows northwesterly through Tongass Narrows (2) past the mouth of Ward Cove. This current plus the tidal current produce a net current with a velocity of 1.2 knots during flood tide stages, then decreases to near zero during tidal ebb. Current measurements made in Ward Cove show a strong influence from eddies formed by the flow of water in Tongass Narrows past the cove. This suggests that dispersal of deeper waters from Ward Cove is largely by the slow process of eddy diffusion below the surface layer.

In the Ward Cove estuary, a surface layer of fresh water and mill effluent, which is less dense than the subsurface layers, results in the establishment of a stratified layer that persists throughout the winter and following summer. This stratification is sufficiently well developed so that vertical mixing is greatly inhibited. The

concentration of pollutants in Ward Cove and adjacent waters generally are less in winter than in summer because of the increased rate of transfer from Ward Cove to Tongass Narrows as a result of the intense winter storms and the high runoff from Ward Creek.

Water Uses

Prior to the establishment of the pulp mill, Ward Cove served as a fish passage zone and nursery area. Some young salmon from Ward Creek still pass through the cove and sustain a small run, but the cove has been and appears to continue to be sufficiently polluted to preclude its use as a nursery area. Adult salmon utilize the deep waters of the cove where little sulfite waste liquor (SWL) occurs. It is doubtful they do more than pass through the area. Food organisms for salmon have been significantly reduced.

The recreational uses of Ward Cove have been reduced to limited sport fishing for salmon. Log rafts often occupy as much as one half of the cove, and access for fishing thus is curtailed.

Previous Studies

Water quality data for Ward Cove and Tongass Narrows collected between October 1, 1951 and September 30, 1952 (3), prior to construction of the pulp mill, show that the dissolved oxygen in surface water varied from a low of 7.8 milligrams per liter (mg/l) during the winter to nearly 12 mg/l during the spring. At the 50-foot depth, dissolved oxygen varied from 7.8 to over 10 mg/l. The five-day biochemical oxygen demand (BOD) was less than 2 mg/l, a value typical of clean

waters. At the time of the 1951-1952 surveys, the only wastes discharged to Ward Cove were from the seasonally operated cannery and the fish wastes reduction plant. Water quality degradation from these facilities was highly localized and mostly seasonal, and was evidenced by reduced populations of aquatic life. Other portions of the cove, however, supported a great variety of marine organisms indicative of clean waters.

Data from unpublished reports from the State of Alaska document the onset of water quality deterioration in Ward Cove between 1952 and 1960, after the Ketchikan Pulp Company began discharging wastes (4). Biological data in these reports show a decline in the number and kinds of marine organisms, and sludge accumulation with associated putrescent odors of hydrogen sulfide.

Studies conducted during August 1965 (5) revealed extremely high sulfite waste liquor (SWL) concentrations throughout the surface waters of Ward Cove. The threshold toxicity (50 mg/l) of SWL to salmon fingerlings, herring, candlefish, euphausids, copepods, and mysids was exceeded. The study also showed significantly less dissolved oxygen in Ward Cove than in Tongass Narrows. The decrease ranged from 4.7 to 1.5 mg/l at the surface, 0.6 to 1.6 mg/l at the 10-meter depth, and 1.0 to 2.5 mg/l at the 40-meter depth. Such degradation was attributed to the combination of effluent biochemical oxygen demand, sludge-bed BOD, and the inhibiting effect of pulp mill wastes on phytoplankton. Throughout much of the cove the dissolved oxygen levels were less than the recommended value (6 mg/l) at the time of

the study. The pH ranged from 6.94 to 7.12 units in the cove, and in Tongass Narrows from 7.68 to 8.02. The Ward Cove pH values were below those for unpolluted sea-waters, and were caused by the combined effects of a low pH effluent diluted into the surface waters, excessive carbon dioxide production from biochemical waste decomposition, and reduced photosynthesis, a process that produces oxygen during daylight periods as a result of green plant activity (phytoplankton and other marine plants) in the water.

The 1968-1969 study by the Federal Water Quality Administration (1) showed that the level of treatment (chemical recovery process) provided by the Ketchikan Pulp Company was insufficient to assure compliance with the existing Alaska Water Quality Standards (6). At that time, wastewater treatment was essentially not existent except for chemical recovery systems for partial recapture and ultimate recycling of magnesium oxide and sulfur dioxide. Sanitary wastes were discharged untreated and non-chlorinated to Ward Cove.

Of 276 samples taken in the top 20 meter layer of the area studied from May 1968 through May 1969, 50% had sulfite waste liquor concentrations greater than 44 mg/l, 35% had greater than 100 mg/l, and 11% greater than 500 mg/l (SWL at a concentration of 10 mg/l is damaging to the immature forms of several kinds of indigenous fishes and shellfish important in the food chain involving salmon and mankind). The typically high concentrations of SWL were found primarily in the upper 5 meters of water and were persistent in all of Ward Cove and

involved significant reaches of Tongass Narrows. The study area affected by high SWL concentrations (50 or more mg/1) amounted to 1.4 square miles.

The 1968-1969 study also showed that dissolved oxygen concentrations were reduced throughout the entire surface waters of Ward Cove to a depth of 15 meters and in the surface waters adjacent to the mouth of the cove in Tongass Narrows to a depth of one meter during the October 1968 sampling period. Of 413 dissolved oxygen measurements taken at depths up to 40 meters from May 1968 through May 1969, 37% were below the minimum acceptable criterion of 6.0 mg/1. Additionally, of 336 measurements made in the upper 29 meters of water, 35% were less than the 6.0 mg/1 criterion. These substantially-reduced dissolved oxygen findings were attributed to inadequately treated wastewater discharges from the pulp mill. Such discharges had high concentrations of sulfite waste liquor and substantial quantities of settleable solids (primarily lost wood fibers from the pulp refining process) that resulted in sludge deposits. The decomposition of these wastes exerted a tremendous demand on the oxygen resources of Ward Cove and Tongass Narrows and reduced the oxygen in the water.

WATER QUALITY STANDARDS

The present Alaska Water Quality Standards (7) designate the marine waters of the state, including Ward Cove and Tongass Narrows, as Class C, D, E, and G. Beneficial uses of marine waters include water contact recreation, industrial water supply, growth and propagation of aquatic life and waterfowl, fur-bearers, and other water-associated life. The standards criteria associated with marine waters that are of particular interest in this report are those for dissolved oxygen, residues in the form of floating solids and sludge deposits, and toxic substances. Of the various classifications, Class D and E have the most stringent criteria:

Dissolved Oxygen

Class D - greater than 6 mg/l in salt water.

Class E - greater than 6 mg/l in the larvae stage. Greater than 5 mg/l in the adult stage.

Residues

Class D - residues may not make the receiving water unfit or unsafe for the uses of this classification; nor cause a film or sheen upon, or discoloration of, the surface of the water or adjoining shoreline; nor cause a sludge or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom or upon adjoining shorelines. Residues shall be less than those levels which cause tainting of fish or other organisms and less than acute or chronic problems as determined by bioassay.

Class E - same as Class D.

Toxic Substances

Class D - concentrations shall be less than those levels which cause tainting of fish, less than acute or chronic problem levels as revealed by bioassay or other appropriate methods and below concentrations affecting the ecological balance.

Class E - same as Class D.

SAMPLING PROGRAM

As stated earlier, the sampling of the waters of Ward Cove and Tongass Narrows was done while routine in-plant surveys of the pulp mill were being conducted. The receiving water sampling was conducted to determine the improvements, if any, in water quality since the mill's installation and operation of its primary treatment plant for pulp processing wastewaters. Sufficient data were available from previous studies to compare with the 1974 findings reported herein to assay the magnitude of any significant improvements in water quality as related to the Alaska Water Quality Standards.

Previous studies revealed that degradation of water quality occurred primarily in the top 10 meters of water. For this reason, and because it was believed that any gross improvements in water quality would first be apparent in these upper water reaches, the 1974 sampling program for dissolved oxygen, pH, temperature, conductivity, and sulfite waste liquor was restricted to the top 12 meters of water in Ward Cove and Tongass Narrows. Additionally, the bottom deposits were also sampled for the same reasons. Chemical tests for sulfides, percent volatile solids, and total organic nitrogen and visual inspections for macroscopic animal components were also conducted on the samples from the bottom deposits. Their general composition was also noted.

Sampling Stations

Fifteen stations were previously established as the study area in the 1968-1969 sampling program. During the 1974 sampling period, the sampling area was extended (Figure 2), and three sampling stations were added to the fifteen studied previously.

Sampling Periods

Although the seasonal variation in water quality of the study area had been evaluated in previous reports (1 and 5) such determinations were beyond the scope of the 1974 sampling period. Additionally, it was believed that any major improvements in water quality would be apparent during any sampling period. Thus, only one was chosen, but the intensity and coverage of the 1974 sampling program in the top 12 meters of water were increased to offset anomalous situations that might occur because of tidal variations. Therefore, sampling for the selected chemical and physical parameters in the water column were confined to periods of two flooding tides and two ebbing tides. The tidal data, and the beginning and end of the sampling periods are as follows:

September 10, 1974

Time of High Tide: 0905	Time of Beginning of Sampling: 0930
Time of Low Tide: 1432	Time of Ending of Sampling: 1250
Time of Low Tide: 1432	Time of Beginning of Sampling: 1555
Time of Next High Tide: 2054	Time of Ending of Sampling: 1830

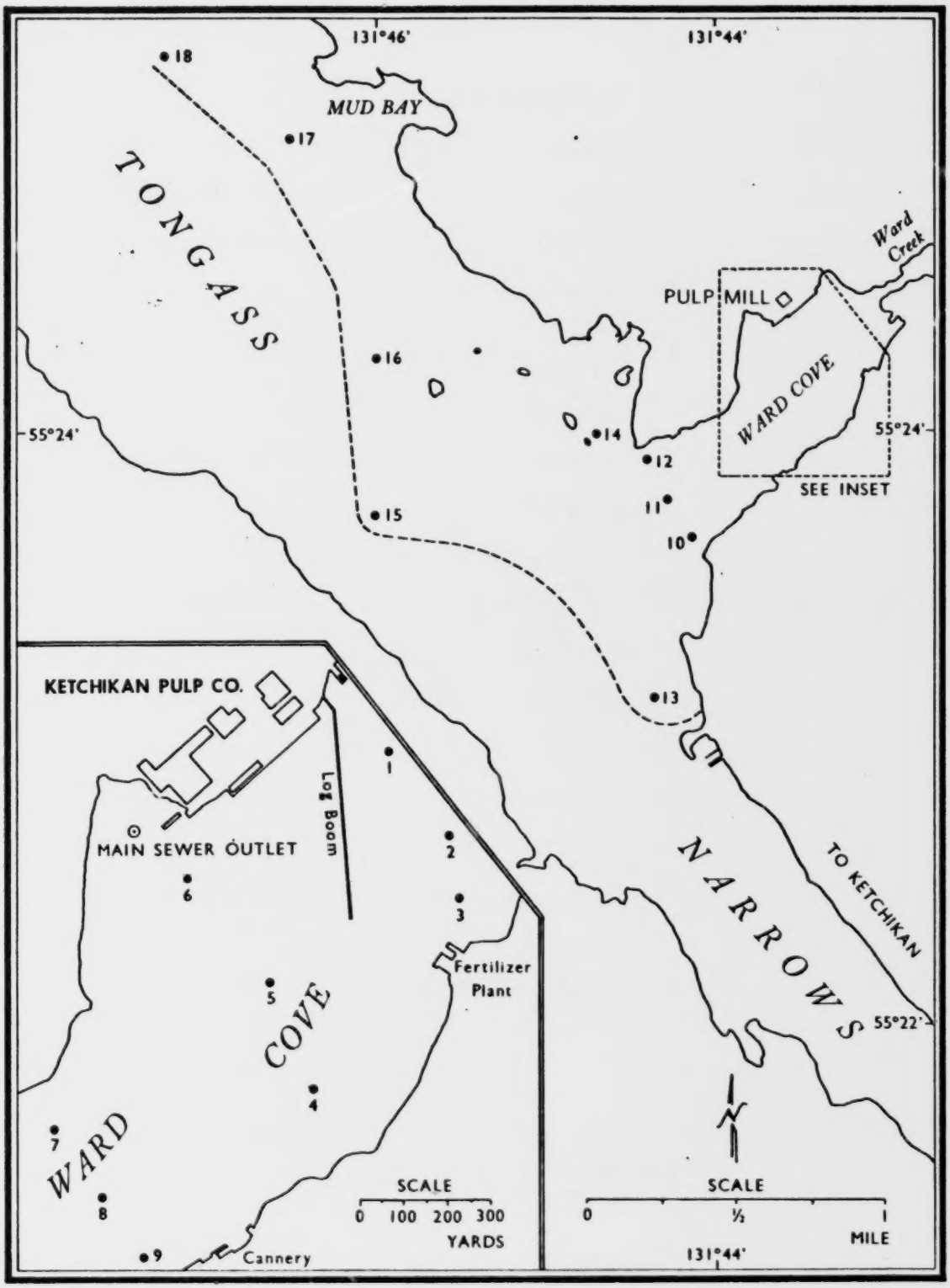

FIGURE 2. The Ward Cove - Tongass Narrows Study Area and Location of Sampling Stations (the area to the right of the dotted line depicts distribution of Sulfite Waste Liquor).

September 11, 1974

Time of Low Tide: 1605
Time of Next High Tide: 2219

Time of Beginning of Sampling: 1600
Time of Ending of Sampling: 1900

September 12, 1974

Time of High Tide: 1134
Time of Next Low Tide: 1719

Time of Beginning of Sampling: 1345
Time of Ending of Sampling: 1600

The sampling route was always along the numerical sequence of station numbers (i.e. from Station 1 through Station 18) during each tidal segment.

Methods

Dissolved oxygen, temperature, conductivity, and pH were determined with a Hydrolab Model 6D Surveyor Portable Water Monitor* instrument that frequently was calibrated each sampling period, for example, the beginning and end of each sampling cycle. Additionally, the dissolved oxygen probes of this instrument were calibrated to the standard Winkler method each time a suspected erratic value for this parameter was obtained.

Salinity determinations were calculated from the conductivity and temperature data obtained with the Hydrolab instrument. Sulfite waste liquor samples were collected in cubitainers, and shipped via air freight in ice-packed containers to the U.S. Environmental Protection Agency laboratory in Seattle, Washington where SWL concentrations were measured using the Pearl-Benson Index method of analysis (8).

*Use of product and company names is for identification only and does not constitute endorsement by the U.S. Environmental Protection Agency.

The pH probe of the Hydrolab instrument did not function properly throughout the course of the 1974 survey, so only a very limited amount of pH determinations were made.

Chemical analysis of the bottom deposit samples were made at the same laboratory facility. As with the SWL samples, the bottom deposit samples were packed in ice for preservation prior to air shipment. Bottom deposit samples were obtained by use of a small Petersen dredge. A small portion of each of these samples was collected for chemical analyses and the remainder was inspected for animal life subsequent to screening through a 30 mesh U.S. Standard Sieve. Visual inspections of these samples were made to determine the presence or absence of pulp fiber mats, and odors of the deposits were noted.

RESULTS AND DISCUSSION

Temperature and Salinity

Data from a previous study (1) show that the Ward Cove estuary was stratified with a lens of less-dense and poorly mixed brackish water that overlays subsurface and more saline waters throughout the year. These conditions inhibit vertical mixing because of differences in density in the various water layers and have an important bearing in the distribution of soluble pollutants discharged to the cove, that is, they are located primarily in the surface waters above the 10 meter depth even though the cove generally is much deeper.

As in the previous studies, similar density patterns were found during the present sampling period (Table 1). The more saline, cooler, and therefore denser water is located beneath less saline, warmer, and lighter upper layers. This pattern is so predominant throughout the study area that it can be readily observed in just the temperature and salinity data collected throughout the course of this survey (Table 1A and 1B, Appendix), and is the result of the discharges of non-brackish waters from Ward Creek and from the Ketchikan Pulp Company which are less dense and less saline and generally warmer than the highly saline marine waters deeper in the cove and Tongass Narrows. This pattern also is typical of many other estuaries throughout Southeastern Alaska.

TABLE I

TEMPERATURE, SALINITY AND DENSITY WITH DEPTH (METERS) AT STATIONS 8 AND 11

DEPTH	SEPT. 10, 1974 (1130 HRS) T.°C	So/oo	σ_t	SEPT. 10, 1974 (1630 HRS) T.°C	So/oo	σ_t	SEPT. 11, 1974 (1730 HRS) T.°C	So/oo	σ_t	SEPT. 12, 1974 (1400 HRS) T.°C	So/oo	σ_t
STATION 8												
1	11.5	23.85	18.08	13.0	20.43	15.19	13.0	20.43	15.19	12.5	12.20	8.94
7	11.0	18.36	13.91	11.0	23.17	18.21	10.5	23.17	17.70	11.0	16.29	12.31
10	11.0	20.43	15.50	10.6	23.85	17.96	10.2	23.85	18.28	10.6	16.43	12.47
12	10.5	20.43	15.57	10.5	23.51	17.96	10.2	23.85	18.28	10.6	16.63	12.62
STATION 11												
	(1200 HRS)			(1700 HRS)			(1800 HRS)			(1500 HRS)		
1	11.0	22.49	17.10	13.5	20.43	15.10	12.5	21.80	16.33	11.5	11.54	8.56
7	11.0	21.11	16.03	11.0	21.80	16.56	10.6	24.54	18.74	11.0	15.60	11.78
10	11.0	20.43	15.50	11.0	23.17	18.15	10.5	24.54	18.75	10.5	16.63	12.63
12	10.2	21.80	16.68	10.5	23.17	17.69	10.2	24.54	18.81	10.4	16.63	12.65

Sulfite Waste Liquor

The importance of the above pattern of density and stratification in the waters of Ward Cove and the adjacent reaches of Tongass Narrows is that the majority of the soluble pollutants (mostly sulfite waste liquors discharged from the primary treatment plant) entering the cove are distributed in the uppermost water layers above a depth of 10 meters, as was found in the 1968-1969 study, or above a depth of 7 meters during the September 1974 survey (Table 2).

Of 257 samples taken at 18 stations at 4 depths during the 1974 sampling period, 21 percent (54) had SWL concentrations greater than 50 mg/1 and 33 percent (85) had more than 10 mg/1. Sulfite waste liquor at 50 mg/1 has been shown to be toxic to phytoplankton and salmon fish-food organisms, and magnesium oxide base waste liquors at 10 ppm have been shown to be damaging to some forms of immature (larval) shellfish (9 and 9a).

Sulfite waste liquor at values of 50 or more mg/1 is particularly noticeable in the layer of water at the 1-meter depth. At this depth during the 1968-1969 study (Appendix Table 2A), SWL concentrations, with one exception, were within the same magnitude of concentrations found during the September 1974 survey (the exception being Station 6 in the 1968-1969 study where the SWL concentration was substantially higher*). Thus, the great similarity in SWL concentrations during

*It is highly probable that the actual location of Station 6 in the 1968-1969 study was significantly closer to the main sewer outfall than the actual location sampled in the 1974 survey, despite the implication that Figure 1 indicates identical locations.

TABLE 2

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L)
WITH DEPTH IN METERS IN WARD COVE & TONGASS NARROWS
SEPTEMBER 10, 1974 0930 - 1300 HOURS

	STATION NUMBERS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DEPTH																		
1	56	144	152	128	156	128	260	200	204	76	242	260	-	-	129	-	-	-
7	21	8	9	6	5	9	8	8	5	11	6	15	-	-	6	-	-	-
10	5	5	6	1	6	5	11	5	7	3	3	4	-	-	2	-	-	-
12	5	2	5	2	3	3	4	6	8	5	3	3	-	-	2	-	-	-

TABLE 2 (CONTINUED)

SEPTEMBER 10, 1974 1500 - 1900 HOURS

	STATION NUMBERS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DEPTH																		
1	45	8	16	370	290	336	340	308	316	30	268	240	75	192	33	39	43	-
7	4	7	6	14	30	17	10	8	34	11	7	9	4	9	7	4	4	-
10	3	4	4	5	4	4	4	6	14	-	3	10	3	3	4	5	3	-
12	3	8	5	6	5	6	5	7	10	6	4	3	2	3	2	3	3	-

TABLE 2 (CONTINUED)

SEPTEMBER 11, 1974 1600 - 1900 HOURS

	STATION NUMBERS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DEPTH																		
1	69	75	100	222	872	690	384	212	236	60	86	272	38	107	8	112	39	-
7	5	5	7	7	27	7	9	12	5	2	2	4	5	47	4	6	7	-
10	1	1	27	2	5	3	4	5	2	1k	5	3	3	7	2	2	1k	-
12	5	4	3	3	1k	6	2	3	3	3	3	2	2	4	2	4	1	-

* k - Denotes value less than detectable limits.

TABLE 2 (CONTINUED)

SEPTEMBER 12, 1974 1200 - 1600 HOURS

	STATION NUMBERS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DEPTH																		
1	224	194	250	260	356	264	340	272	228	124	166	146	71	75	32	46	83	82
7	11	5	9	110	4	11	7	7	12	2	8	5	4	5	5	2	2	2
10	7	10	7	3	5	7	4	2	7	3	2	7	2	2	5	1	2	-
12	6	5	5	3	4	9	14	5	3	5	7	4	5	1k	5	1	1	-

* k - Denotes value less than detectable limits.

the two surveys indicates no major reduction in SWL concentrations has been achieved in Ward Cove or Tongass Narrows since the installation of the mill's primary treatment system in 1973. This is to be expected however, because the primary treatment system is designed for removal of settleable solid pollutants rather than dissolved pollutants such as sulfite waste liquor.

It is to be noted, however, that prior to 1971, i.e. during the 1968-1969 study period, strong ("red") waste liquors were periodically discharged without treatment because of lack of adequate red liquor storage facilities. This practice, one not uncommon in the pulping industry at the time, had been discontinued by the time of the September 1974 sampling period. Review of the sulfite waste liquor data for the one-meter depths in Ward Cove for the 1968-1969 study and for the September 1974 sampling period reveals that on three occasions during the 1968-1969 study, sulfite waste liquor was found in concentrations significantly exceeding 1000 mg/l whereas during the September 1974 sampling period sulfite waste liquor concentrations at no time exceeded 1000 mg/l (Appendix Table 2A and Table 2, respectively). Thus the discontinuation of periodically discharging red liquors prior to the September 1974 survey may account for the occasionally very high concentrations (more than 1000 mg/l) of sulfite waste liquor found in 1968-1969 and the lack of such concentrations during the 1974 survey. Therefore, the lower sulfite waste liquor concentration found during the September 1974 sampling period, that is, always less than 1000 mg/l, probably is an indication of minor improvement in Ward Cove as far as

sulfite waste liquor is concerned. The observation that the sulfite waste liquor concentrations found during the 1968-1969 study, other than the three that significantly exceeded 1000 mg/1, are of the same magnitude as those measured during the September 1974 period is evidence that this improvement is only minor.

Because of inadvertent manpower, time, and equipment constraints, only the waters of Tongass Narrows immediately adjacent to the mouth of Ward Cove (Stations 13, 14, and 15) were sampled during the 1968-1969 study. This sampling area was extended northwesterly during the 1974 survey because of the observed highly discolored water northward of Station 14. Thus, sulfite waste liquors were found to occur in the surface waters in significant concentrations about 2.4 miles farther from Ward Cove than indicated in the 1968-1969 study, i.e. Stations 16, 17, and 18 where SWL was found in concentrations greater than 50 mg/1. The total sampling area affected by concentrations of 50 mg/1 of SWL in the surface and near-surface waters, then, is at least 2.0 square miles (Figure 2). No attempt was made to track the distribution of SWL southeasterly of the mouth of Ward Cove because of: 1) time, personnel, and equipment constraints, and 2) the observations from previous studies that revealed the net flow of tidal and other currents in Tongass Narrows is in a northwest rather than southeast direction.

As might be suspected, the average concentration of SWL at the 1-meter depth in Ward Cove (Stations 1-9, 242 mg/1) was found to be much higher than in those of Tongass Narrows (Stations 10-18, 109 mg/1). Except on two occasions (once each at Stations 2 and 15), 10 mg/1 of

sulfite waste liquor were observed throughout the 1-meter depth of the entire study area at all stations sampled. Station 2 is located where periodically strong flushing action occurs as a result of freshwater discharged from Ward Creek, and Station 15 is situated in an area of extensive and frequent dilution and/or mixing resulting from strong tidal and other currents of Tongass Narrows. Sulfite waste liquor concentrations of 10 or more mg/l, a level damaging to many larval forms of several indigenous fishes, were found 22 times at water depths between 7 and 12 meters. This is a frequency of 22 per 194 samples or about 11 percent of the time, and occurred in both Ward Cove and Tongass Narrows.

Dissolved Oxygen

Dissolved oxygen in the near-surface waters of Ward Cove frequently was reduced to less than 6.0 mg/l, the minimum allowed by the water quality standards criterion for this parameter. The near-surface waters (1-meter depth) at Stations 1-6, 9, and 12 always had less than 6.0 mg/l of dissolved oxygen during the 1974 sampling period, except for Stations 4 and 12 which had a value of 6.0 or more mg/l only 25 percent of the time (Table 3). Of all samples (266) collected during the 1974 survey from the 1, 7, 10, and 12 meter depths, about 24 percent had less than 6.0 mg/l of dissolved oxygen (Appendix Table 3A). Of those near the surface, 69 percent had dissolved oxygen concentrations that did not exceed 6.0 mg/l.

There was a notable difference in the quality of the near-surface waters in Ward Cove and Tongass Narrows. Specifically, the frequency

TABLE 3

DISSOLVED OXYGEN CONCENTRATIONS (MG/L) AT 1 METER IN WARD COVE AND TONGASS NARROWS

SEPTEMBER - 1974

DATE (TIME)	STATION NUMBERS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
9/10/74 (0930-1250)	4.5	5.4	4.7	6.3	5.2	5.7	6.1	6.2	5.9	6.6	7.0	6.0	6.8	7.2	7.8	---	---	---
9/10/74 (1555-1830)	4.4	3.5	3.4	3.6	4.4	4.7	3.6	4.7	4.6	6.9	4.8	5.2	6.1	6.0	6.9	7.2	6.8	---
9/11/74 (1600-1900)	3.4	3.7	3.3	2.6	3.8	2.9	2.9	4.8	3.2	6.0	5.8	5.3	6.7	4.7	7.9	6.7	7.3	---
9/12/74 (1345-1600)	1.0	2.5	2.4	3.9	3.0	3.9	2.0	6.8	5.4	4.8	3.5	4.0	5.0	6.6	7.3	7.0	6.0	6.6

of occurrence of very low dissolved oxygen (6.0 mg/1) values was greater in Ward Cove (Stations 1-9) than in Tongass Narrows (Stations 10-18). The averages of the 1-meter values for dissolved oxygen for Ward Cove and Tongass Narrows were 4.0 and 6.2 mg/1, respectively, while the corresponding averages for all depths sampled at these stations was 5.82 and 6.97 mg/1. About 37 percent (54) of all samples (144) in the 1974 survey from Ward Cove (Stations 1-9) had less than 6.0 mg/1 of dissolved oxygen, with dissolved oxygen below 6.0 mg/1 in 75 percent of the samples at Station 1 where the lowest dissolved oxygen value of 1.0 mg/1 was observed.

It is to be noted that the near surface waters of Stations 1, 2, 3, 5, 6 and Station 9 always had less than the 6.0 mg/1 required by the Alaska Water Quality Standards, and that the near-surface waters at Stations 4, 6, 7, 11, and 12 had less than 6.0 mg/1 of dissolved oxygen 75 percent of the time. Correspondingly, the near-surface waters of Stations 10, 13, and 14 had 6.0 or more mg/1 of dissolved oxygen 75 percent of the time while those of Station 8 had less than 6.0 mg/1 50 percent of the time. The remaining sampling stations always were above 6.0 mg/1. At Stations 7-18 there were no violations of the 6.0 mg/1 criterion for dissolved oxygen in the water layer from 7-12 meters deep, whereas in the comparable layer at Stations 1-6 there were frequent violations of this criterion.

It is apparent that sulfite waste liquor is most abundant and widely distributed in the surface layers of the waters of Ward Cove and adjacent Tongass Narrows, and that much of the oxygen demand has

not been accommodated (in terms of the 6.0 mg/l criterion) by the time the sulfite waste liquors and other oxygen-demanding pollutants discharged from the mill have reached Tongass Narrows, where sulfite waste liquor still is to be found in concentrations toxic or otherwise damaging to aquatic animals, i.e., 10 or more mg/l. Correspondingly, sulfite waste liquor is less abundant at the water layer between 1 and 12 meters deep, and much of the oxygen demand from the sulfite waste liquor and other oxygen-demanding pollutants from the mill has been accommodated (again, in terms of the criterion of 6.0 mg/l) by the time these pollutants reach Tongass Narrows where this layer only occasionally contains sulfite waste liquor at concentrations of 10 or more mg/l.

A comparison of the dissolved oxygen data obtained during the 1974 survey with that from similar depths from the 1968-1969 survey (Appendix Table 4A) shows a general similarity in that the dissolved oxygen values in the near-surface waters of Ward Cove (Stations 1-9) were higher than those in Tongass Narrows. This similarity is apparent at other depths, too. Another comparison of the two sets of data, i.e., the values for dissolved oxygen in the surface waters of Ward Cove from the 1968-1969 survey with that from the 1974 survey, reveals that the average concentration was near 5.4 and 4.1 mg/l, respectively. Corresponding calcuations for the waters of Tongass Narrows shows an average of 6.7 and 6.2 mg/l. This general characteristic of the two sets of data is also evident upon comparison of the dissolved oxygen data for all comparable water layers sampled to depths of 12 meters

(the average for Ward Cove in 1968-1969 was 6.5 mg/l while in 1974 it was 5.8 mg/l; in Tongass Narrows the respective values are 7.5 and 7.0 mg/l. Other comparisons are not practicable because of the comparatively small number of values obtained at these depths during any specific period in the 1968-1969 study. For example, the best comparison would be one for the October 8, 1968 period with the September 10-12, 1974 period, but the number of samples in the former is quite small.

On the basis of the above comparisons, however, it is concluded that no major improvements have occurred in the dissolved oxygen concentrations of Ward Cove and the adjacent waters of Tongass Narrows since the 1968-1969 study.

pH

The pH probe on the Hydrolab instrument developed an electrical malfunction immediately after beginning the 1974 survey, so pH data are wanting. Only five pH measurements were obtained: Station 1 at the 1-meter depth was 7.7, at 7 meters 7.8, at 10 meters and 12 meters 7.7, and at 1 meter at Station 2 it was 7.7.

Color

The color of the waters of Ward Cove and Tongass Narrows is light brown because of the natural soluble components draining from the land via the streams in the area, and because of the soluble components discharged from the pulp mill. A Secchi disc, 20 centimeters in diameter, was used to measure the intensity of coloration

in the sampling area because it is one of the criterion listed in the Alaska Water Quality Standards. This criterion is: Secchi disc visible at a minimum depth of 1-meter for Class D and E waters. One set of Secchi disc readings was made during the 1974 survey, on September 10 (Appendix Table 5A).

Only one of the Secchi disc measurements, at Station 6, was below the standards criterion of 1-meter (39 inches), and one, Station 9, just met this criterion. It is to be noted that the lower Secchi disc measurements were found in the cove waters near the main sewer outfall adjacent to Station 6. The wastewaters from this outfall are highly discolored with brown dissolved substances such as sulfite waste liquor, tannins and lignins, and other chemicals from the pulping and bleaching processes in the mill.

Chemical Aspects of Bottom Deposits

Chemical analyses of the bottom deposits were not conducted in previous studies, so no such data are available to compare with the findings of the 1974 survey. Nevertheless, samples were taken for chemical analyses in order to establish a baseline set of parameters for comparison with any subsequent surveys that may be made of these deposits. The analyses conducted on the bottom samples collected during this survey consisted of organic nitrogen, chemical oxygen demand, total solids, total volatile solids, and total sulfides (Table 4).

Marine deposits that are not influenced by wastewater discharges containing organic settleable solids commonly are characterized as

TABLE 4

WARD COVE SEDIMENT ANALYSES

SEPTEMBER 13, 1974

STATION NUMBER	TOTAL ORGANIC NITROGEN (G/KG, DRY WEIGHT)	TOTAL SOLIDS (% OF WET WEIGHT)	TOTAL VOLATILE SOLIDS (% OF TOTAL SOLIDS)	TOTAL SULFIDES (G/KG, DRY WEIGHT)	CHEMICAL OXYGEN DEMAND (G/KG, DRY WEIGHT)
2	4.2	18.7	32.7	4.3	460
5	3.6	41.7	11.1	2.0	147
7	6.8	10.1	46.3	1.8	655
8	7.3	21.9	27.7	1.5	408
9	5.7	30.3	19.4	3.2	159
10	5.9	21.8	22.7	2.1	321
11	6.9	19.9	24.0	1.7	312
12	7.5	17.9	46.9	3.0	601

having less than 0.1 gram of organic nitrogen per kilogram of sample, less than 5 percent volatile solids, near or less than 0.1 gram of sulfides per kilogram of samples, and chemical oxygen demand (COD) of less than 5.0 grams per kilogram of sample (10). It is readily apparent than, that the sediments in Ward Cove are grossly contaminated with organic matter.

The mixture of gross quantities of organic matter with liquids and inert materials found in the samples from these stations has been called sludge in the previous reports of studies and was observed to be widespread throughout Ward Cove. Samples collected in the 1974 survey at Cove stations other than Stations 2, 5, 7, 8, 9, 10, 11, and 12 also consisted primarily of sludge as visually determined. No attempt was made to collect samples of the bottom deposits at Station 15 because of its great depth (33 fathoms - too deep for the sampling gear) but samples were collected at Stations 13, 14, and 16. These consisted primarily of sand, pebbles, and/or small rocks, and shell fragments of bottom dwelling types of organisms. Bottom deposits at Stations 17 and 18 were not sampled because they were judged on the basis of findings at Stations 14 and 16 to be out of the zone of settleable solids deposition caused by mill effluents.

Further inspection of the data in Table 4 in conjunction with previous study observations and mill activities provide an interpretation of these data. Specifically, Station 2 is located in an area where there is much log handling activity which results in deposition of lost wood solids; hence, the very high values for COD and volatile

solids. Station 5 is in an area fairly well distant from intensive log handling activity and somewhat distant from the mill's main sewer outfall; it thus is less laden with organic matter than Stations 2 and 7. Except for Station 10 which is located where there may be some moderately strong eddy currents, Stations 7-12, even though farther from the mill's main sewer than Station 5, have significantly higher values for COD, volatile solids, and organic nitrogen than Station 5 and are suspected to define the primary zone where settleable organic matter from the main sewer accumulates. The extremely high values for COD (greater than 500 g/kg) and volatile solids (greater than 40 percent) shown for Stations 7 and 12 may be the combined result of settleable organic matter accumulating there from the mill's outfall plus lost wood solids from the intensive log handling activities nearby, i.e. by Station 7.

Visual and Biological Aspects of Bottom Deposits

Visual and biological inspection of samples from the bottom deposits in Ward Cove and the adjacent waters of Tongass Narrows were considered to be equally important as the sampling of the upper 12 meters of water because, as in the upper 12 meters of water, changes in the visual and biological characteristics of the deposits, if any, would be expected to occur more or less concurrently with, and possibly independent of, any changes in the upper 12 meters of water (oxygen-demanding solid pollutants such as wood fibers and other settleable solids contained in the mill

effluent prior to the installation and operation of the primary treatment facility would be widely distributed in the surface waters, then slowly settle to the bottom in the study area where some were subsequently re-suspended by bulking processes to again precipitate to the bottom).

During the 1968-1969 study, bottom samples were obtained for visual and biological inspection only at Stations 2, 5, 6, 9-11, and Stations 13 and 14. Only a few small animals, primarily tube dwelling polychaete worms and remnants of other organisms, were found in the sludges at these stations which commonly had pulp fibers and wood chips. Much fiber-containing sludge was noted in the bottom reaches near Station 6 and bulked sludge with its conspicuous mat of fibers was noted near the main mill and other sewer outfalls. Hydrogen sulfide bubbles rising to and then bursting on the surface undoubtedly were apparent too, but were not reported.

During the 1974 survey, no hydrogen sulfide bubbles were observed on the surface of Ward Cove even though this gas was apparent in many of the bottom samples. Similarly, no mats of pulp fibers were found in the bottom samples from the study area, and polychaete worms were common at most of the stations sampled (no polychaete worms or other macroscopic animals were observed at Stations 1 and 6). These observations are significant because they reveal that the installation and operation of the primary treatment facility for wastewaters from the pulping process in the mill has resulted in a perceptible improvement

in the bottom reaches of the Ward Cove study area. There remained, however, a paucity in the variety of organisms at the stations in Ward Cove and the immediately adjacent reaches in Tongass Narrows, a feature indicative that the improvement process is nowhere near complete.

REFERENCES CITED

1. United States Department of the Interior, Federal Water Quality Administration, Region X, Alaska Operations Office, "Effects of Pulp Mill Wastes on Receiving Waters at Ward Cove, Alaska", October 1970.

2. U.S. Department of the Interior, Federal Water Pollution Control Administration, Northwest Region, "Ketchikan, Alaska Bacteriological Survey", August 1969.

3. Alaska Water Pollution Control Boards, State of Alaska, Report No. 7, "Ward Cove Survey". Ketchikan, Alaska. August 1953.

4. Alaska Water Pollution Control Board, State of Alaska, First Draft, "Ward Cove Survey, 1949-1957". Ketchikan, Alaska. September 1957.

5. U.S. Department of the Interior, Federal Water Pollution Control Administration, Northwest Region. "Oceanographic and Related Water Quality Studies in Southeastern Alaska, August 1965". Portland, Oregon. July 1966.

6. State of Alaska, Department of Health and Welfare, "Alaska State Plan, Water Quality Standards for Interstate Waters Within the State of Alaska". June 20, 1967, Revised November 10, 1967, and May 24, 1970.

7. State of Alaska, Department of Environmental Conservation, "Water Quality Standards", as revised October 1973.

8. Barnes, C.A., et al, "A Standardized Pearl-Benson, or Nitroso, Method Recommended for Estimation of Spent Sulfite Liquor or Sulfite Waste Liquor Concentrations in Waters", Tappi 46(6): 247-251, 1963.

9. U.S. Department of the Interior, Federal Water Pollution Control Administration, and Washington State Pollution Control Commission, "Pollutional Effects of Pulp and Paper Mill Wastes in Puget Sound", Portland, Oregon, and Olympia, Washington, March 1967.

9a. Woelke, Charles E., Timothy Schink, and Eugene Sanborn, "Effect of Biological Treatment on the Toxicity of Three Types of Pulping Wastes to Pacific Oyster Embryos", State of Washington, Department of Fisheries, March 1972.

10. U.S. Environmental Protection Agency, Region X, "The Effects of Dredging on Water Quality in the Northwest", July 1971.

Preceding page blank

APPENDIX TABLE 1A

SALINITY WITH DEPTH (METERS) IN WARD COVE AND TONGASS NARROWS

SEPTEMBER 10, 1974 0930 - 1300 HOURS

STATION #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DEPTH																		
1	21.11	17.67	23.85	23.85	21.11	21.11	21.11	23.85	21.11	21.11	22.49	20.43	19.05	18.36	20.43	-----	-----	-----
7	21.11	23.85	25.91	25.91	22.49	22.49	22.49	18.36	23.17	23.17	21.11	22.49	21.80	21.11	21.11	-----	-----	-----
10	25.56	24.20	26.59	26.59	23.17	23.17	22.49	20.43	23.85	23.85	20.43	23.85	22.49	21.80	22.49	-----	-----	-----
12	25.56	24.20	26.59	26.59	22.49	22.49	23.17	20.43	23.85	23.85	21.80	23.85	23.17	25.91	21.80	-----	-----	-----

SEPTEMBER 10, 1974 1545 - 1830 HOURS

1	20.43	21.11	20.43	21.80	20.43	18.36	19.05	20.43	19.05	19.74	20.43	19.05	19.39	18.36	18.36	21.11	19.05	-----
7	22.49	23.51	23.17	23.85	23.17	22.14	22.49	23.17	22.49	22.14	21.80	22.49	22.49	21.80	19.74	24.20	20.08	-----
10	23.51	22.49	23.85	24.88	23.51	22.83	22.83	22.85	23.51	22.49	23.17	23.51	23.51	22.49	22.49	23.85	21.11	-----
12	23.51	23.17	25.91	24.20	23.85	23.85	22.49	23.51	22.83	-----	23.17	23.51	23.51	23.51	21.80	24 54	23.51	-----

SEPTEMBER 11, 1974 1600 - 1900 HOURS

1	19.05	23.17	23.85	21.11	19.74	21.11	20.43	20.43	20.43	21.11	21.80	19.05	18.01	18.36	20.43	21.11	18.01	-----
7	19.05	26.94	25.91	25.22	23.85	23.85	22.49	23.17	23.17	23.85	24.54	23.51	22.49	21.80	23.17	22.49	22.49	-----
10	21.80	27.28	26.94	25.22	24.20	24.54	22.49	23.85	23.85	24.54	24.54	22.49	21.80	22.49	23.85	22.49	21.80	-----
12	21.11	27.28	19.05	25.22	24.20	24.88	23.85	23.85	24.20	24.54	24.54	23.17	22.49	22.49	23.85	23.17	22.49	-----

SEPTEMBER 12, 1974 1245 - 1600 HOURS

1	8.94	10.23	-----	0.11	13.89	13.89	13.89	12.20	9.58	7.45	11.54	13.21	4.14	12.87	0.18	10.23	14.23	17.32
7	16.63	15.60	15.60	14.91	16.22	16.29	16.29	16.29	15.74	15.60	15.60	15.60	15.26	16.29	16.29	16.29	16.29	19.74
10	17.32	16.63	16.29	16.29	16.43	16.63	16.63	16.43	16.43	16.29	16.63	16.63	16.98	16.63	16.43	16.63	16.29	-----
12	16.98	16.98	16.63	16.63	17.32	16.63	16.63	16.63	16.63	16.98	16.63	16.43	16.98	17.39	16.63	16.63	16.29	-----

APPENDIX TABLE 1B

TEMPERATURE WITH DEPTH (METERS) IN WARD COVE AND TONGASS NARROWS

SEPTEMBER 10, 1974 0930 - 1300 HOURS

STATION #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DEPTH																		
1	13.2	12.5	12.2	12.5	12.5	11.5	11.5	11.5	11.5	11.5	11.0	12.5	12.5	12.5	12.5	----	----	----
7	11.0	10.2	11.0	10.2	11.5	11.0	11.0	11.0	11.5	11.5	11.0	11.0	11.0	11.5	11.5	----	----	----
10	10.2	10.0	10.0	10.0	10.0	10.5	10.5	11.0	11.5	10.5	11.0	10.0	10.5	11.0	11.0	----	----	----
12	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.5	10.5	10.0	10.2	10.0	10.2	10.0	10.6	----	----	----

SEPTEMBER 10, 1974 1545 - 1830 HOURS

1	11.5	12.5	12.6	12.6	12.5	12.5	12.5	13.0	13.0	12.5	13.5	13.5	12.5	12.5	12.5	12.6	12.5	----
7	11.0	11.5	11.0	11.0	11.0	11.5	11.0	11.0	10.8	11.0	11.0	11.0	10.8	11.0	11.5	11.0	11.0	----
10	10.8	10.5	10.5	10.6	10.5	10.5	10.5	10.6	10.5	10.6	11.0	10.8	10.6	10.6	11.0	10.5	10.5	----
12	10.6	10.5	10.6	10.5	10.5	10.5	10.5	10.5	10.6	----	10.5	10.5	10.6	10.7	10.8	10.5	10.5	----

SEPTEMBER 11, 1974 1600 - 1900 HOURS

1	12.0	12.2	12.4	12.6	14.5	13.5	12.7	13.0	13.0	12.5	12.5	12.5	12.2	12.5	11.5	12.5	12.5	----
7	10.6	10.6	11.5	10.7	10.7	10.6	10.5	10.5	11.0	10.5	10.6	10.4	10.5	10.5	11.0	11.0	11.0	----
10	10.4	10.5	10.4	10.2	10.5	10.2	10.4	10.2	10.5	10.5	10.5	10.2	10.4	10.2	10.5	10.8	10.5	----
12	10.0	10.0	10.0	10.2	10.0	10.5	10.2	10.2	10.2	10.5	10.2	10.2	10.4	10.2	10.5	10.5	10.5	----

SEPTEMBER 12, 1974 1245 - 1600 HOURS

1	12.5	12.5	----	13.6	12.6	13.5	13.5	12.5	12.6	12.6	11.5	12.5	12.2	12.0	12.8	11.7	12.5	12.5
7	11.0	11.0	11.0	11.2	11.2	11.5	11.0	11.0	11.2	11.2	11.0	11.5	11.0	10.8	11.5	11.2	11.5	11.5
10	10.6	10.7	10.5	10.5	10.6	10.8	10.5	10.6	10.7	10.5	10.5	10.5	10.8	10.5	10.5	11.0	11.0	----
12	10.6	10.6	10.6	10.6	10.6	10.4	10.4	10.6	10.6	10.5	10.4	10.2	10.6	10.2	10.5	10.8	11.0	----

APPENDIX TABLE 2A

SULFITE WASTE LIQUOR CONCENTRATIONS (MG/L) WITH DEPTH (METERS) IN WARD COVE AND TONGASS NARROWS, 1968-1969

Depth	STATION NUMBERS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							MAY 10, 1968								
1	101	129	161	261	418	2040	374	880	418	446	519	350	178	37	---
5	---	---	---	40	44	175	49	148	50	24	23	37	43	19	---
10	---	---	---	---	---	---	<5	<5	36	---	---	---	---	---	---
							JULY 3, 1968								
1	---	214	214	303	415	---	376	2070	260	311	231	208	30	221	---
7	---	15	8	<5	<5	---	<5	<5	<5	<5	<29	<5	<5	<5	---
							JULY 7, 1968								
1.5	11	8	21	9	11	---	13	11	10	23	17	23	---	---	---
							OCTOBER 8, 1968								
1	---	60	---	---	1111	244	---	142	---	---	80	---	---	---	7
10	---	---	---	---	26	<5	---	<5	---	---	<5	---	---	---	<5

APPENDIX TABLE 2A (CONTINUED)

Depth	STATION NUMBERS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							OCTOBER 9, 1968								
1	---	---	---	---	---	---	---	---	---	---	---	33	8	46	---
7	---	---	---	---	---	---	---	---	---	---	---	---	---	<5	---
							DECEMBER 18, 1968								
1	45	---	---	203	483	---	162	---	---	104	84	12	---	20	---
							APRIL 13, 1969								
1	---	99	---	---	269	336	---	34	---	---	159	185	8	---	76
5	---	9	---	---	42	18	---	32	---	---	8	<5	<5	---	8
10	---	<5	---	---	8	8	---	8	---	---	<5	<5	---	---	<5
							MAY 13, 1969								
1	---	76	---	---	184	---	---	272	---	---	206	---	---	---	---
6	---	44	---	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	12	---	---	---	---	---	---	---	---	---	---

APPENDIX TABLE 3A

DISSOLVED OXYGEN CONCENTRATIONS (MG/L) WITH DEPTH (METERS) IN WARD COVE AND TONGASS NARROWS

SEPTEMBER 10, 1974 0930 - 1250 HOURS

	STATION NUMBERS														
Depth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	4.5	5.4	4.7	6.3	5.2	5.7	6.1	6.2	5.9	6.6	7.0	6.0	6.8	7.2	7.8
7	5.3	6.4	6.2	6.7	6.6	6.3	6.7	6.9	7.4	7.9	7.2	7.0	7.7	7.5	8.2
10	5.5	6.3	6.3	7.6	7.1	6.5	6.7	7.9	7.8	8.0	8.3	7.4	7.8	7.8	8.2
12	4.5	6.1	5.9	7.2	6.9	6.5	6.7	7.6	7.7	8.2	8.3	7.6	7.9	6.9	8.2

APPENDIX TABLE 3A (CONTINUED)

SEPTEMBER 10, 1974 1555 - 1830 HOURS

	STATION NUMBERS																
Depth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	4.4	3.5	3.4	3.6	4.4	4.7	3.6	4.7	4.6	6.9	4.8	5.2	6.1	6.0	6.9	7.2	6.8
7	5.0	6.3	5.6	5.4	5.5	6.0	6.0	6.2	6.2	6.9	6.2	6.2	6.5	6.4	6.9	7.4	7.0
10	5.5	6.2	6.0	6.4	6.6	5.8	6.0	6.6	6.5	7.0	7.2	7.3	7.5	6.5	7.5	7.4	7.2
12	5.5	6.1	5.7	6.6	6.5	5.1	6.3	7.0	6.9	7.3	7.3	6.8	7.7	6.6	7.7	7.6	7.4

APPENDIX TABLE 3A (CONTINUED)

SEPTEMBER 11, 1974 1600 - 1900 HOURS

	STATION NUMBERS																
Depth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	3.4	3.7	3.3	2.6	3.8	2.9	2.9	4.8	3.2	6.0	5.8	5.3	6.7	4.7	7.9	6.7	7.3
7	4.9	5.6	6.0	5.7	5.3	5.2	5.7	6.4	6.4	7.1	6.7	6.3	6.9	6.4	7.6	7.2	7.2
10	5.2	6.0	6.2	6.4	6.0	5.7	6.0	6.9	6.6	7.5	7.4	6.7	7.7	6.6	7.9	7.5	7.6
12	4.7	5.9	6.1	6.6	6.7	6.1	6.4	7.3	6.9	7.5	7.4	7.0	7.8	6.6	7.9	7.6	7.9

APPENDIX TABLE 4A

DISSOLVED OXYGEN CONCENTRATIONS (MG/L) AT SELECTED DEPTHS (METERS) IN WARD COVE AND TONGASS NARROWS, 1968-1969

Depth	STATION NUMBERS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							MAY 10, 1968								
1	3.8	4.6	4.6	5.9	5.9	---	8.3	---	8.5	---	---	---	---	---	---
7	---	5.7	7.0	7.0	7.0	---	---	---	8.8	---	---	---	---	---	---
11	---	5.7	6.4	7.2	7.0	---	---	---	---	---	---	---	---	---	---
							MAY 15, 1968								
1	5.7	5.6	5.9	5.4	4.3	5.4	6.2	6.9	5.3	6.7	6.1	5.1	---	---	---
7	---	---	8.0	8.4	8.3	8.2	8.0	9.0	8.8	8.8	8.6	8.2	---	---	---
11	---	---	6.7	8.4	7.6	7.4	7.7	8.3	8.8	8.5	7.8	7.7	---	---	---
							JULY 3, 1968								
1	---	---	1.8	2.2	4.5	2.9	4.8	4.0	3.7	---	7.0	---	---	---	---
7	---	---	4.8	5.9	6.1	5.9	6.2	7.0	6.7	---	7.5	---	---	---	---
11	---	---	5.4	6.6	6.2	6.1	7.0	7.0	4.6	----	8.2	---	---	---	---

APPENDIX TABLE 4A (CONTINUED)

Depth	STATION NUMBERS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							JULY 8, 1968								
1	---	---	8.3	---	---	---	---	8.3	---	---	8.6	---	---	---	---
7	---	---	8.2	---	---	---	---	7.8	---	---	7.7	---	---	---	---
10	---	---	8.0	---	---	---	---	---	---	---	---	---	---	---	---
							OCTOBER 8, 1968								
1	---	3.9	---	---	3.2	2.9	---	2.4	---	---	2.8	3.6	---	5.9	8.1
5	---	4.3	---	---	5.4	5.0	---	6.7	---	---	6.8	5.6	---	5.9	---
10	---	---	---	---	5.5	1.9	---	7.5	---	---	7.6	5.8	---	---	7.9
							APRIL 13, 1969								
1	---	9.5	---	---	8.3	8.3	---	8.4	---	---	8.9	8.1	---	---	9.7
7	---	9.7	---	---	9.2	9.4	---	9.3	---	---	9.3	8.9	---	---	9.6
10	---	9.5	---	---	9.3	9.1	---	8.7	---	---	---	8.9	---	---	9.5

APPENDIX TABLE 5A

SECCHI DISK (20CM) MEASUREMENTS IN METERS

FOR WARD COVE AND TONGASS NARROWS

SEPTEMBER 10, 1974 0900 - 1300 HOURS

STATION #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1.9	1.8	1.7	1.1	1.1	0.9	1.1	1.1	1.0	1.9	1.2	1.1	2.0	1.1	1.6